

The New Central Texas Land Use Land Cover Classification Project

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Abstract: The New Central Texas Land Use Land Cover (LULC) Classification Project was conducted by the Spatial Sciences Lab (SSL) at Texas A&M University as a continuation of the University of Texas at Austin Center for Space Research's The New Eastern Texas Land Use Land Cover Classification Project in achieving an up-to-date, moderate-resolution LULC dataset for input in meteorological, biogenic and photochemical modeling. LandSat TM satellite images, with acquisition dates between the years 2000 and 2002, covering sixty counties surrounding the Interstate 35 corridor, were classified in respect to the Texas Land Classification System (TLCS) implemented by the Texas Geographic Information Council (TGIC) in 1999 by utilizing an object-based classification scheme through Definien's Professional 5.0 software. The classification was enhanced with the use of the 2001 National Land Cover Dataset (NLCD) derived by the United States Geological Survey (USGS), Common Land Unit (CLU) data provided by the United States Department of Agriculture (USDA) – Farm Service Agency (FSA), and the National Hydrography Dataset (NHD) produced by USGS.

Introduction

The New Central Texas Land Use Land Cover (LULC) Classification project is the second phase, "Phase 2", in refining the National Land Cover Dataset (NLCD) 2001 (U.S. Geological Survey, 2005) to meet the Texas Commission on Environmental Quality's (TCEQ) standards for air modeling. Wells (2006) reiterates Homer et al. (2004) by stating "The NLCD 2001 was intended to serve as a starting point for national and regional land cover projects requiring specialized refinements." The goal of The New Central Texas LULC is to generate a LULC classification for the Interstate Highway 35 (IH-35) corridor and surrounding counties according to the Texas Land Classification System of 1999 at a minimum mapping unit of 2 acres, equivalent to 3 pixels by 3 pixels. To achieve this goal, the SSL employed Definien's Professional 5.0 (Definien's) software to perform an object-based classification.

Methods

Study Area

The study area covers sixty counties along the IH-35 corridor (an area of 162,511 square kilometers). Figure 1 delineates the study area and highlights the counties with Common Land Unit (CLU) data obtained from the United States Department of Agriculture (USDA) – Farm Service Agency (FSA).

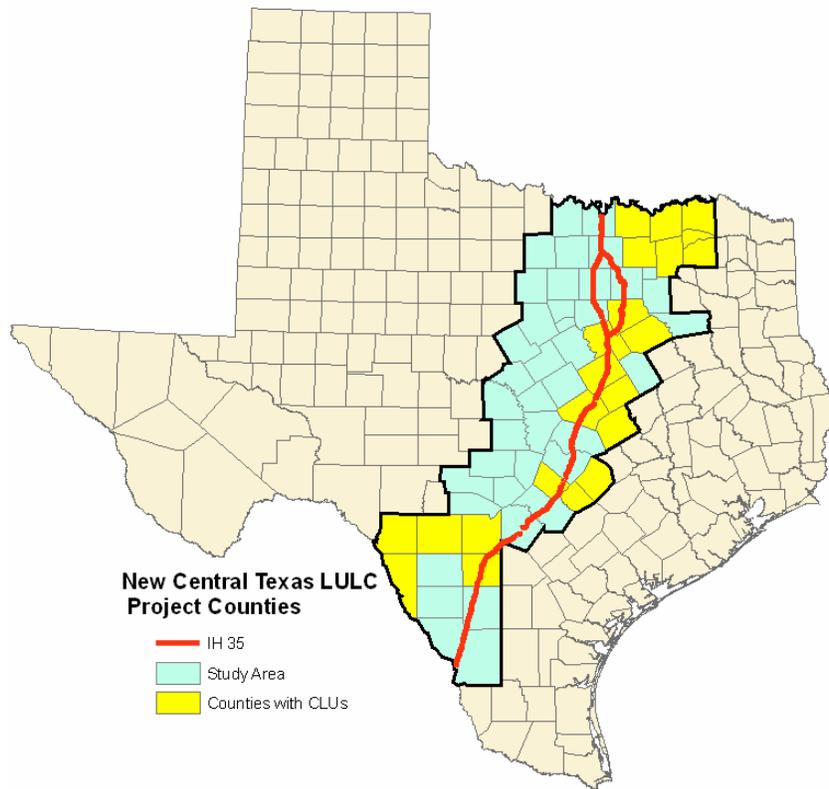


Figure 1. Map of the study area for the New Central Texas LULC Classification Project with counties having CLU data highlighted.

Data

LandSat TM imagery was used for this study because of its moderate resolution and availability for free download. Covering the study area required fifteen images. Fifteen leaf-off and fifteen leaf-on LandSat TM images, for a total of 30 LandSat TM images, were downloaded from the USGS data download website (<http://glovis.usgs.gov/>).

Path	Row	Leaf-off Date	Leaf-on Date
26	37	2/23/2002	6/15/2002
26	38	2/23/2002	8/12/2000
26	39	2/23/2002	9/29/2000
27	37	3/15/2001	5/21/2002
27	38	11/3/2002	5/21/2002
27	39	11/3/2002	7/21/2001
27	40	2/3/2001	7/21/2001
27	41	12/28/2001	7/21/2001
28	37	2/2/2001	9/30/2001
28	38	3/9/2002	6/13/2002
28	39	3/9/2002	6/13/2002
28	40	12/16/2000	7/12/2001
28	41	2/21/2002	7/12/2001
29	39	2/25/2001	9/14/2002
29	40	2/25/2001	9/18/2000

Table 1. List of LandSat TM imagery obtained.

The 2001 National Land Cover Database (NLCD) performed by United States Geological Survey (USGS) was used for the four levels of Developed Area.

Common Land Units (CLU) were used to help delineate the Cultivated Herbaceous areas. CLUs are obtained by hand digitizing the outline of areas used for agricultural purposes. CLU data was obtained for the following twenty two counties: Bastrop, Bell, Caldwell, Collin, Delta, Ellis, Falls, Fannin, Frio, Grayson, Hays, Hill, Hopkins, Hunt, Kinney, Lamar, Maverick, McLennan, Medina, Milam, Navarro, and Uvalde.

The National Hydrography Dataset (NHD) was also obtained from USGS. It includes streams and rivers, lakes and ponds, and inundation areas.

Field data was collected using a Delorme Earthmate PN-20 Global Positioning System (GPS) handheld receiver to be used as training samples for classification. A total of # points were collected over a 4 day driving period with two teams. The points were chosen because they were at least 2 acres in size making them identifiable in the imagery and they were a good representative of the class. These data points focused on vegetation classes that would be hard to discern from the imagery (i.e. woodland vs. forest, types of evergreen). Figures 2 through 5 represent the documentation and verification of field data process.

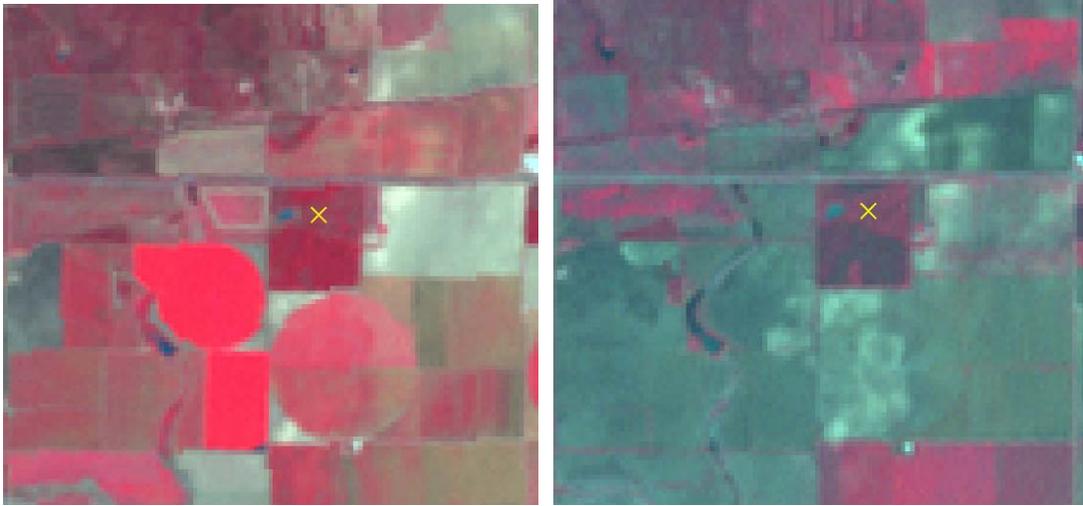


Figure 2. Leaf-on (left) and leaf-off (right) Landsat TM images of a ground truth point.



Figure 3. Ground photo to show height relative to person.

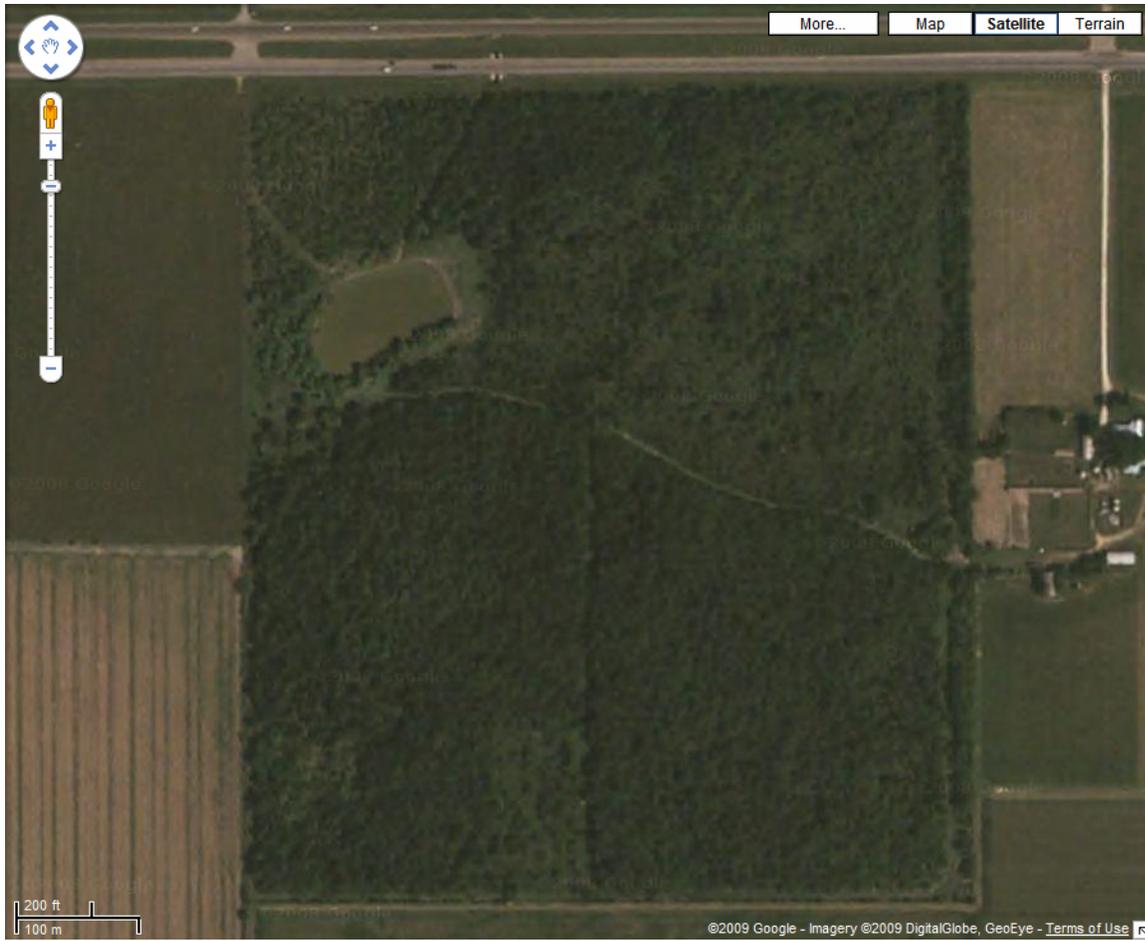


Figure 4. Google Maps screen shot of aerial imagery.



Figure 5. When possible a ground photo taken by Google Maps is also examined.

From these figures an LULC is assigned. This particular point is determined to be a Mixed Woodland close to the road and Deciduous Forest farther off the road.

Classification Schema

The classification schema is carried over from The New Eastern Texas LULC Classification project which used the Texas Land Classification System (TLCS) implemented by the Texas Geographic Information Council (TGIC, 1999). Table 2 shows the classification schema adopted for the project.

Label	Acronym	Description
1	OW	Open Water
2	DOS	Developed Open Space
3	DLI	Developed Low Intensity
4	DMI	Developed Medium Intensity
5	DHI	Developed High Intensity
6	BL	Barren Land (Rock/Sand/Clay/Unconsolidated Shore)
7	HN	Herbaceous Natural
8	HC	Herbaceous Cultivated
9	WFR	Riparian Forested Wetland
10	WFS	Swamp Forested Wetland
11	WS	Shrub Wetland
12	WHE	Herbaceous Emergent Wetland
13	FDC	Cold-Deciduous Forest
14	FEB	Broad-leafed Evergreen Forest
15	FEN	Needle-leafed Evergreen Forest
16	FM	Mixed Forest
17	CWV	Cultivated Woody Vegetation
18	WDC	Cold-Deciduous Woodland
19	WEB	Broad-leafed Evergreen Woodland
20	WEN	Needle-leafed Evergreen Woodland
21	WM	Mixed Woodland
22	SDC	Cold-Deciduous Shrub
23	SEB	Broad-leafed Evergreen Shrub
24	SEN	Needle-leafed Evergreen Shrub
25	SM	Mixed Shrub
26	SDS	Desert Scrub

Table 2. Classification schema used in the New Central Texas LULC Project.

The Broad-leafed Evergreen Shrub does not exist in this classification because this type of shrub was found to be either the understory of a forest or woodland, or was in a mixed shrub area during the fieldwork portion of this project. The class could also be responsible for turning the Cold-Deciduous Forest and Woodland classes into Mixed Forest and Woodland, respectively. When analyzing the leaf-off image, the evergreen shrub's spectral value is picked up, leading to the belief that there are evergreen trees there, when in actuality it is just the understory of a deciduous forest or woodland. Also, the Cultivated Woody Vegetation class is not included in the classification. The spatial resolution of Landsat TM imagery does not afford the luxury of extracting orchards or vineyards based on organized planting of trees.

Image Classification

Every image was classified. The classifications were done one Landsat TM scene at a time in most cases. Some pairs of images were mosaicked because they had the same acquisition date. Mosaicking all the images together would result in an extremely large dataset having incongruent spectral characteristics because the images had different acquisition dates. The following images were mosaicked: leaf-on 2637 and 2638, leaf-on 2738 and 2739, leaf-on 2838 and 2839, leaf-on 2939 and 2940, leaf-off 2737 and 2738, leaf-off 2739 and 2740, leaf-off 2838 and 2839, and leaf-off 2840 and 2841.

The first step in the object-based classification method is to segment the image. Object-based classification relies on the principal of segmentation, which groups contiguous, similar pixels into clusters using user defined parameters of homogeneity. In Definien's software package, homogeneity is defined by scale parameter, color, shape, compactness, and smoothness. The other parameter that can be manipulated is Layer Weight. Layer weighting determines the amount of information from each layer that is used in the segmentation process, with a higher number giving a heavier weight. Figure 6 describes the segmentation parameters and how they relate to each other.

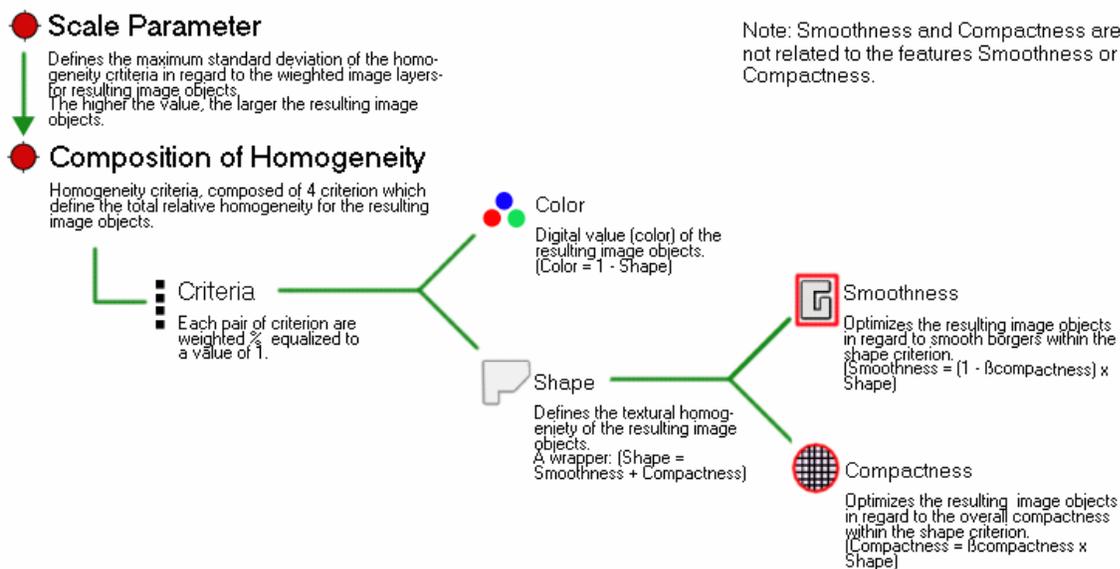


Figure 6. Hierarchy diagram of the segmentation process and description of each parameter. Definien's Professional 5 Reference Book, 2006.

All the images were segmented with the same parameters, shown in Figure 7, with the resulting segmentation shown in Figure 8.

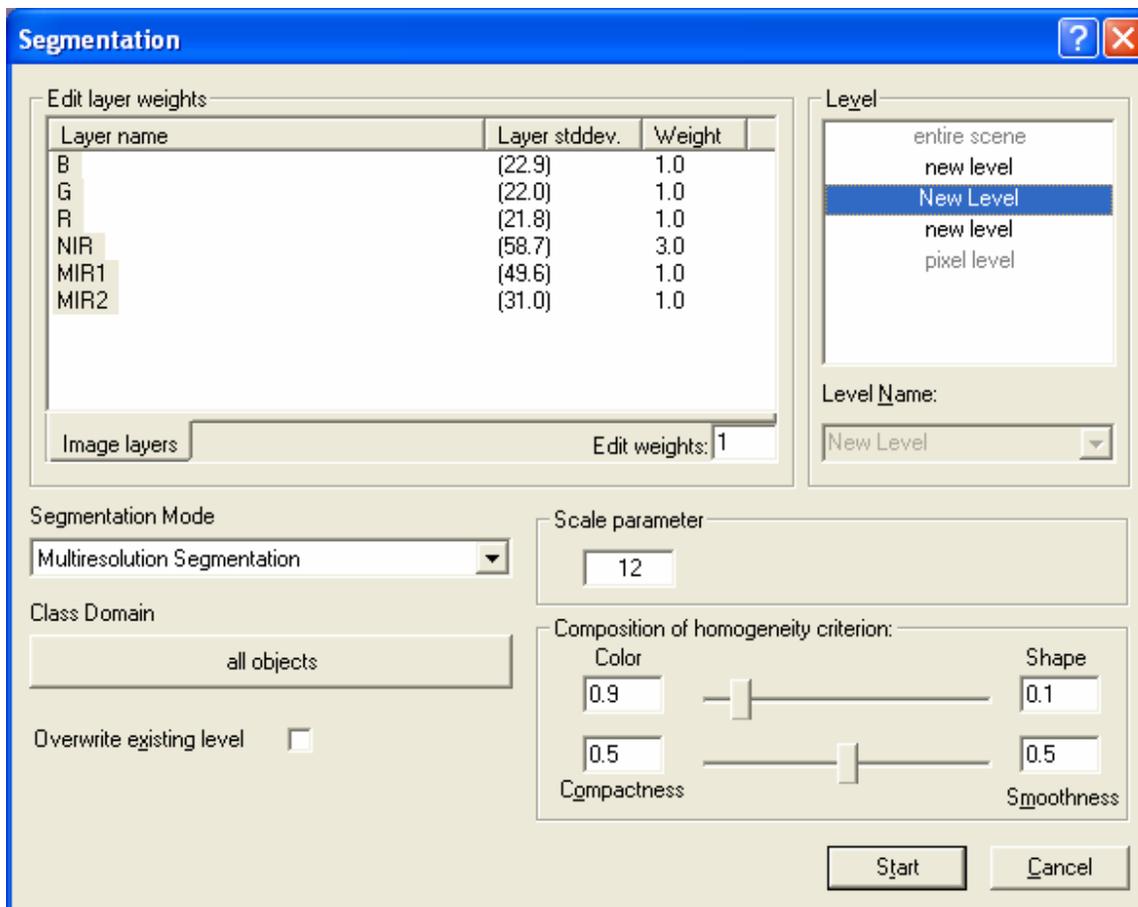


Figure 7. Segmentation dialogue showing the segmentation parameters used for all images.

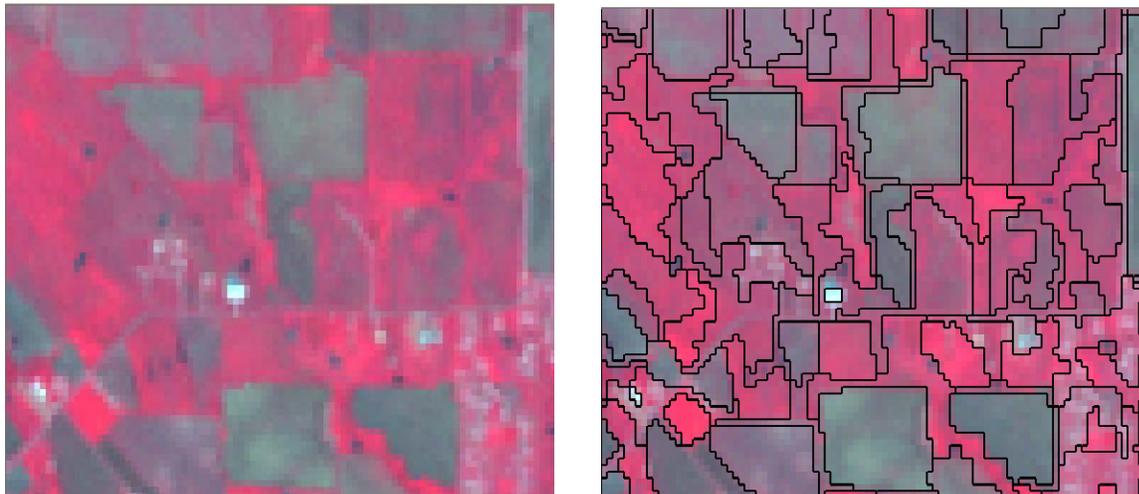


Figure 8. Subset of an image showing the original image and image with object outlines after segmentation.

As in a supervised classification, training samples were collected. These samples were chosen by observing the characteristics in both the leaf-on and leaf-off images, the use of Google Earth, and user judgment. Google Maps was very helpful in that it provided higher resolution imagery

than LandSat. Google Maps also has a feature that allows observation of the land cover from the perspective of a vehicle on the road. This helped to discriminate between Forest and Woodland and Shrub more effectively. Because CLU data was not available for the entire study area, the Herbaceous Cultivated class needed to be classified as well. Only areas in the growing stage were chosen as training samples for the Herbaceous Cultivated class.

Post Classification

The Herbaceous Cultivated class was extracted from each classification and mosaicked to serve as an overlay. The same was done for Cold-Deciduous classes from the leaf-on images. The leaf-off classifications were mosaicked. The Herbaceous Cultivated overlay was overlaid on the classification and then the Cold-Deciduous.

The ancillary data needed to be prepared for overlay on the image classification. The 2001 NLCD contains four classes that are pertinent to this study: Developed Open Space, Developed Low Intensity, Developed Medium Intensity, and Developed High Intensity (together, referred to as Developed Areas). These classes were extracted from the NLCD. CLU data is stored in vector format as a shapefile and is conducted on a county by county basis. The counties had to be merged and then converted to raster format using ArcMap. After the CLU data had been merged and converted it was then combined with the Developed Areas and overlaid on the classification.

Riparian areas are “tree dominated wetlands along stream and river courses” (TGIC, 1999). This description leads to question the exact definition. In higher resolution data, it can be determined that trees in riparian areas, or just near streams and rivers in general, are larger, and often more vibrant, than trees not much farther away from the streams and rivers. The NHD stream data is digitized from aerial photos and shows the center line of the streams and rivers. Measuring the distance from the river to the edge of these larger trees on aerial photographs of different sizes of streams and rivers, gave a general guideline of the distance these could be found from a stream. It could range from a single tree width in agricultural areas to a hundred meters or more along the main channel of a large river. An arbitrary distance of 75 meters was chosen as a suitable standard. After deciding on a distance within which Riparian Forested Wetlands might be found, the NHD streams were buffered to 75 meters. Any area classified as woodland or forest within the buffer was changed to Riparian.

The NHD also provides a shapefile with a class labeled “inundation area,” analogous to wetlands. As with the Riparian areas, pixels within the “inundation area” and classified as forest or woodland were reclassified as Swamp Forested Wetland, as shrub were reclassified as Shrub Wetland, and those classified as Herbaceous Natural were reclassified as Herbaceous Emergent Wetland.

Within the study area there is only one pocket of needle-leaved evergreen trees. This area is located just east of Bastrop, TX, and is known as the Lost Pines. A shapefile was created surrounding the Lost Pines and then used as a mask for changing pixels classified as Broad-leaved Evergreen to Needle-leaved Evergreen. After all of these steps were completed, the classification was complete.

The classification was then clipped to each county and converted to a shapefile for use in modeling.

Results and Discussion

Classification

A new land use and land cover dataset was completed for the IH 35 corridor and surrounding counties as defined by TCEQ. A color coded-map of the dataset is shown in Figure 9.

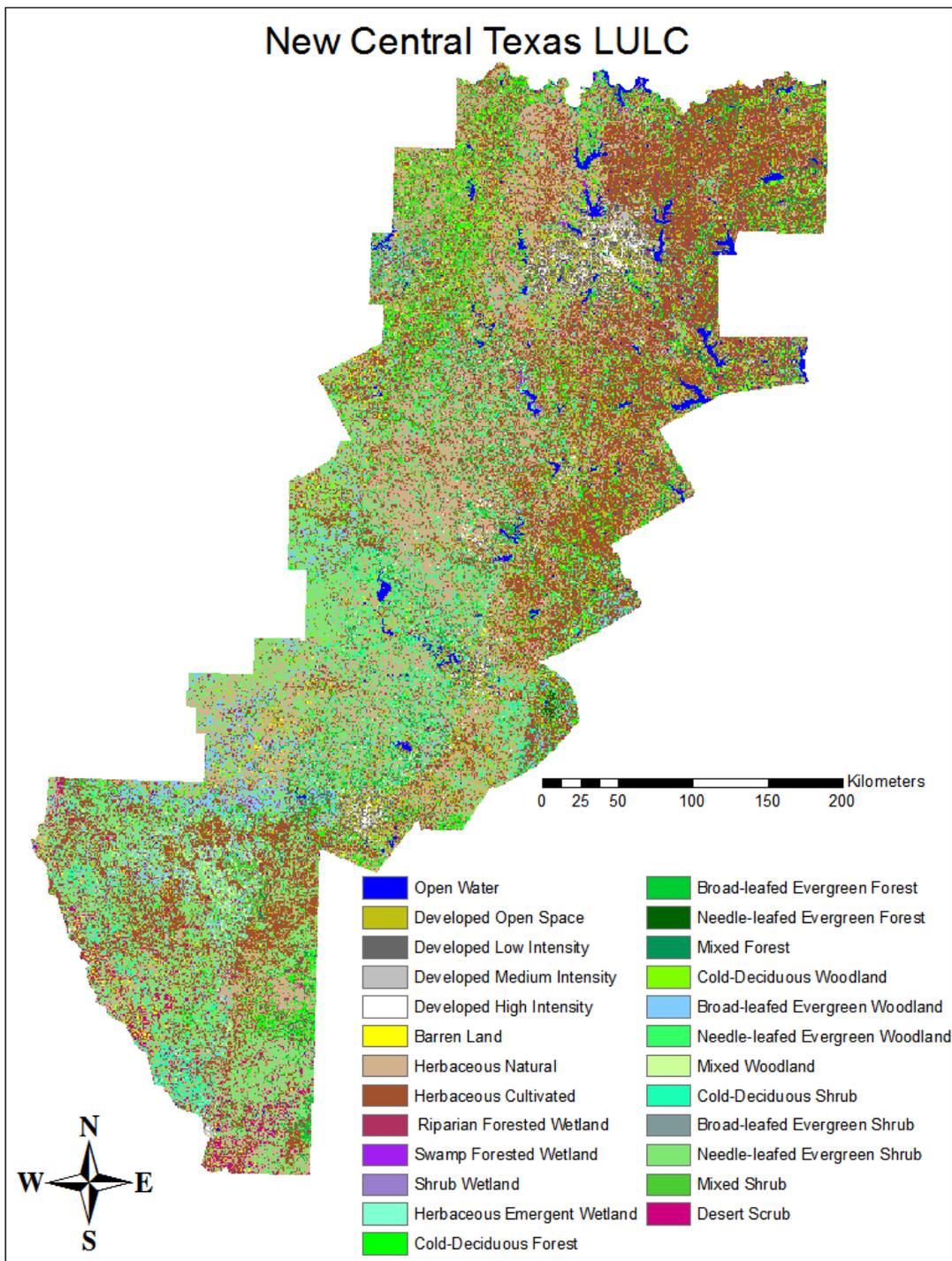


Figure 9. Map of The New Central Texas LULC Classification Project.

Statistics

Table 3 shows the distribution of classes throughout the study area. The most abundant classes are Herbaceous Cultivated and Herbaceous Natural. Needle-leaved Evergreen Shrubs are the most abundant woody vegetation type.

CLASS	# PIXELS	AREA SQ.	
		KM	% AREA
OW	2919004	2627.1036	1.62%
DOS	9769160	8792.244	5.41%
DLI	4735601	4262.0409	2.62%
DMI	1978373	1780.5357	1.10%
DHI	939735	845.7615	0.52%
BL	1544715	1390.2435	0.86%
HN	37249434	33524.4906	20.63%
HC	43096290	38786.661	23.87%
WFR	10385671	9347.1039	5.75%
WFS	234890	211.401	0.13%
WS	124436	111.9924	0.07%
WHE	146349	131.7141	0.08%
FDC	8278793	7450.9137	4.58%
FEB	3135136	2821.6224	1.74%
FEN	79991	71.9919	0.04%
FM	1465065	1318.5585	0.81%
CWV	0	0	0.00%
WDC	5255526	4729.9734	2.91%
WEB	5235950	4712.355	2.90%
WEN	48267	43.4403	0.03%
WM	1645459	1480.9131	0.91%
SDC	7623350	6861.015	4.22%
SEB	0	0	0.00%
SEN	28958786	26062.9074	16.04%
SM	3894502	3505.0518	2.16%
SDS	1823199	1640.8791	1.01%
TOTAL	180567682	162510.9138	

Accuracy Assessment

An assessment of producer's and user's accuracy was performed for the study area. The classification covered 24 LULC classes, but accuracy was only tested for 20. The four Developed Area classes were taken directly from the NLCD 2001 and are more accurate than SSL personnel could achieve. A stratified random sample of 1,800 point locations was generated. For each point, one of the 20 cover types was assigned by visual inspection of the

leaf-off and leaf-on Landsat TM images used in the classification, Google Earth imagery, and 2 meter resolution false-color composite imagery obtained for the National Agriculture Imagery Program (NAIP) during leaf-on 2006. Table 3 provides the accuracy assessment for at the TLCS 1999 level of detail. The full error matrix is attached in the appendix.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Open Water	65	63	62	95.38%	98.41%
Developed Open Space	0	2	0	---	---
Developed Low Intensity	0	1	0	---	---
Developed Medium Intensity	0	0	0	---	---
Developed High Intensity	0	0	0	---	---
Barren Land	56	99	54	96.43%	54.55%
Herbaceous Natural	330	239	181	54.85%	75.73%
Herbaceous Cultivated	218	267	164	75.23%	61.42%
Riparian Forested Wetland	97	103	84	86.60%	81.55%
Swamp Forested Wetland	36	37	28	77.78%	75.68%
Shrub Wetland	18	30	14	77.78%	46.67%
Herbaceous Emergent Wetland	24	32	18	75.00%	56.25%
Cold-Deciduous Forest	82	91	40	48.78%	43.96%
Broad-leafed Evergreen Forest	52	65	43	82.69%	66.15%
Needle-leafed Evergreen Forest	34	50	34	100.00%	68.00%
Mixed Forest	90	57	39	43.33%	68.42%
Cultivated Woody Vegetation	0	0	0	---	---
Cold-Deciduous Woodland	62	76	35	56.45%	46.05%
Broad-leafed Evergreen Woodland	86	74	46	53.49%	62.16%
Needle-leafed Evergreen Woodland	29	50	24	82.76%	48.00%
Mixed Woodland	71	58	29	40.85%	50.00%
Cold-Deciduous Shrub	71	85	34	47.89%	40.00%
Broad-leafed Evergreen Shrub	1	0	0	---	---
Needle-leafed Evergreen Shrub	129	197	94	72.87%	47.72%
Mixed Shrub	189	70	37	19.58%	52.86%
Desert Scrub	60	54	39	65.00%	72.22%
Totals	1800	1800	1099		

Overall Classification Accuracy = 61.06%

Table 3. Producer's and User's Accuracy Table.

As can be seen in the error matrix, most accuracy is lost among woody vegetation classes. To satisfy curiosity, the accuracy table was modified to show the accuracy for the merger of merger

of forest and woodland classes by type (i.e. Cold-Deciduous Forest and Cold-Deciduous Woodland), merger of Mixed with class mistaken for, merger of Forest and Woodland of type and Mixed, merger of Mixed at Shrub level, and merger of Forest and Woodland with Mixed eliminated and Shrub with Mixed eliminated. This provided five extra accuracy assessments shown in Tables 4.

Classification Detail	Accuracy
Original TLCS	61.06%
Forest and Woodland of Type combined	63.22%
Mixed Eliminated at Tree level	63.17%
Forest and Woodland with Mix eliminated	65.33%
Shrub Mix eliminated	64.00%
F&W with Tree and Shrub Mix eliminated	68.28%

The other large area of error is located in the region southwest of San Antonio. This is not as easily identifiable in the error matrix. The classification classifies the shrub classes as Herbaceous Natural and Herbaceous Cultivated. This may be due to the dryness of the area.

Future Options

Using LandSat TM imagery makes it difficult to create a suitable classification at the high level of detail sought by the TLCS 1999. Future considerations could be made to classifying National Agriculture Imagery Program (NAIP) imagery, even if it is resampled to 5, 10, or 15 meter pixels. However, NAIP imagery is limited in that it is only available during leaf-on conditions.

Another possible direction future projects could take is to adjust the NLCD 2001. This would require only classifying the areas that do not match up with the NLCD 2001, following the original intention of the NLCD 2001. Also, using the canopy cover product generated for the NLCD 2001 could be of use in determining the difference between woodland and forest more easily.

Fieldwork may also want to be considered during the leaf-off season. This would allow for much easier identification of vegetation type in the field.

References

Definiens AG. 2006. Definiens Professional 5 Reference Book. München, Germany.

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Texas Geographic Information Council, 1999, Texas land classification system: recommendations for new land use land cover datasets for Texas, a report to the GIS Managers Committee. Available from <http://www.dir.state.tx.us/tgic/pubs/pubs.htm>. Last accessed August 26, 2005.

Wells, G. 2006. The New Eastern Texas Land Use Land Cover Classification Project. Texas Commission on Environmental Quality.

U.S. Geological Survey. 2005. National Land Cover Database 2001 (NLCD 2001) home page. Available from http://www.mrlc.gov/mrlc2k_nlcd.asp.

Appendix

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : u:/tceq/updated_classification/tceq_final4.img

User Name : jstukey1

Date : Thu Feb 26 07:55:56 2009

ERROR MATRIX

Classified Data -----	Unclassifi -----	Open Water -----	Developed -----	Reference Data
				Developed -----
Unclassified	0	0	0	0
Open Water	0	62	0	0
Developed Open	0	0	0	0
Developed Low I	0	0	0	0
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	0	1	0	0
Herbaceous Natu	0	0	0	0
Herbaceous Cult	0	0	0	0
Riparian Forest	0	0	0	0
Swamp Forested	0	0	0	0
Shrub Wetland	0	0	0	0
Herbaceous Emer	0	0	0	0
Cold-Deciduous	0	0	0	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Forest	0	1	0	0
Cultivated Wood	0	0	0	0
Cold-Deciduous	0	0	0	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Woodland	0	0	0	0
Cold-Deciduous	0	0	0	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Shrub	0	1	0	0
Desert Scrub	0	0	0	0

Column Total	0	65	0	0
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Reference Data

Classified Data	Developed	Developed	Barren Lan	Herbaceous
Unclassified	0	0	0	0
Open Water	0	0	0	1
Developed Open	0	0	0	0
Developed Low I	0	0	0	0
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	0	0	54	17
Herbaceous Natu	0	0	1	181
Herbaceous Cult	0	0	0	54
Riparian Forest	0	0	0	2
Swamp Forested	0	0	0	1
Shrub Wetland	0	0	0	7
Herbaceous Emer	0	0	0	4
Cold-Deciduous	0	0	0	9
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Forest	0	0	0	0
Cultivated Wood	0	0	0	0
Cold-Deciduous	0	0	1	11
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Woodland	0	0	0	0
Cold-Deciduous	0	0	0	12
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	13
Mixed Shrub	0	0	0	17
Desert Scrub	0	0	0	1
Column Total	0	0	56	330

Reference Data

Classified Data	Herbaceous	Riparian F	Swamp Fore	Shrub Wetl
Unclassified	0	0	0	0
Open Water	0	0	0	0

Developed Open	0	0	0	0
Developed Low I	0	0	0	0
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	11	0	0	0
Herbaceous Natu	6	0	0	0
Herbaceous Cult	164	0	0	0
Riparian Forest	0	84	0	0
Swamp Forested	0	2	28	1
Shrub Wetland	1	1	4	14
Herbaceous Emer	4	0	3	2
Cold-Deciduous	12	0	0	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Forest	2	1	1	0
Cultivated Wood	0	0	0	0
Cold-Deciduous	6	0	0	1
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	0	0
Mixed Woodland	1	0	0	0
Cold-Deciduous	4	5	0	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	2	3	0	0
Mixed Shrub	5	0	0	0
Desert Scrub	0	1	0	0
Column Total	218	97	36	18

Reference Data

Classified Data	Herbaceous	Cold-Decid	Broad-leaf	Needle-lea
Unclassified	0	0	0	0
Open Water	0	0	0	0
Developed Open	0	0	0	0
Developed Low I	0	0	0	0
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	0	0	0	0
Herbaceous Natu	0	4	0	0
Herbaceous Cult	0	1	2	0
Riparian Forest	1	4	1	0
Swamp Forested	4	0	0	0

Shrub Wetland	1	1	0	0
Herbaceous Emer	18	0	0	0
Cold-Deciduous	0	40	0	0
Broad-leafed Ev	0	3	43	0
Needle-leafed E	0	0	0	34
Mixed Forest	0	6	1	0
Cultivated Wood	0	0	0	0
Cold-Deciduous	0	11	0	0
Broad-leafed Ev	0	0	4	0
Needle-leafed E	0	4	0	0
Mixed Woodland	0	2	0	0
Cold-Deciduous	0	3	1	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	3	0	0
Mixed Shrub	0	0	0	0
Desert Scrub	0	0	0	0
Column Total	24	82	52	34

Classified Data	Reference Data			
	Mixed Fore	Cultivated	Cold-Decid	Broad-leaf
Unclassified	0	0	0	0
Open Water	0	0	0	0
Developed Open	1	0	1	0
Developed Low I	0	0	0	0
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	0	0	0	0
Herbaceous Natu	0	0	4	2
Herbaceous Cult	1	0	2	3
Riparian Forest	0	0	2	2
Swamp Forested	0	0	1	0
Shrub Wetland	0	0	0	0
Herbaceous Emer	0	0	0	1
Cold-Deciduous	5	0	8	3
Broad-leafed Ev	9	0	0	6
Needle-leafed E	11	0	0	0
Mixed Forest	39	0	0	1
Cultivated Wood	0	0	0	0
Cold-Deciduous	3	0	35	0
Broad-leafed Ev	3	0	0	46

Needle-leafed E	10	0	0	0
Mixed Woodland	3	0	0	0
Cold-Deciduous	3	0	5	3
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	0	2	17
Mixed Shrub	2	0	2	2
Desert Scrub	0	0	0	0
Column Total	90	0	62	86

Reference Data

Classified Data	Needle-lea	Mixed Wood	Cold-Decid	Broad-leaf
-----	-----	-----	-----	-----
Unclassified	0	0	0	0
Open Water	0	0	0	0
Developed Open	0	0	0	0
Developed Low I	0	0	0	0
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	0	0	2	0
Herbaceous Natu	0	1	4	1
Herbaceous Cult	0	3	8	0
Riparian Forest	0	1	4	0
Swamp Forested	0	0	0	0
Shrub Wetland	0	0	0	0
Herbaceous Emer	0	0	0	0
Cold-Deciduous	0	4	4	0
Broad-leafed Ev	0	1	0	0
Needle-leafed E	5	0	0	0
Mixed Forest	0	2	0	0
Cultivated Wood	0	0	0	0
Cold-Deciduous	0	3	0	0
Broad-leafed Ev	0	1	1	0
Needle-leafed E	24	12	0	0
Mixed Woodland	0	29	0	0
Cold-Deciduous	0	4	34	0
Broad-leafed Ev	0	0	0	0
Needle-leafed E	0	6	13	0
Mixed Shrub	0	4	0	0
Desert Scrub	0	0	1	0
Column Total	29	71	71	1

Classified Data -----	Reference Data -----			Row Total -----
	Needle-lea -----	Mixed Shru -----	Desert Scr -----	
Unclassified	0	0	0	0
Open Water	0	0	0	63
Developed Open	0	0	0	2
Developed Low I	0	1	0	1
Developed Mediu	0	0	0	0
Developed High	0	0	0	0
Barren Land	0	3	11	99
Herbaceous Natu	10	18	7	239
Herbaceous Cult	11	15	3	267
Riparian Forest	1	1	0	103
Swamp Forested	0	0	0	37
Shrub Wetland	0	1	0	30
Herbaceous Emer	0	0	0	32
Cold-Deciduous	3	3	0	91
Broad-leafed Ev	1	2	0	65
Needle-leafed E	0	0	0	50
Mixed Forest	0	3	0	57
Cultivated Wood	0	0	0	0
Cold-Deciduous	1	4	0	76
Broad-leafed Ev	5	14	0	74
Needle-leafed E	0	0	0	50
Mixed Woodland	1	22	0	58
Cold-Deciduous	2	9	0	85
Broad-leafed Ev	0	0	0	0
Needle-leafed E	94	44	0	197
Mixed Shrub	0	37	0	70
Desert Scrub	0	12	39	54
Column Total	129	189	60	1800

----- End of Error Matrix -----

ACCURACY TOTALS

Class	Reference	Classified	Number	Producers	Users
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Name	Totals	Totals	Correct	Accuracy	Accuracy
-----	-----	-----	-----	-----	-----
Unclassified	0	0	0	---	---
Open Water	65	63	62	95.38%	98.41%
Developed Open Space	0	2	0	---	---
Developed Low Intensity	0	1	0	---	---
Developed Medium Intensity	0	0	0	---	---
Developed High Intensity	0	0	0	---	---
Barren Land	56	99	54	96.43%	54.55%
Herbaceous Natural	330	239	181	54.85%	75.73%
Herbaceous Cultivated	218	267	164	75.23%	61.42%
Riparian Forested Wetland	97	103	84	86.60%	81.55%
Swamp Forested Wetland	36	37	28	77.78%	75.68%
Shrub Wetland	18	30	14	77.78%	46.67%
Herbaceous Emergent Wetland	24	32	18	75.00%	56.25%
Cold-Deciduous Forest	82	91	40	48.78%	43.96%
Broad-leafed Evergreen Forest	52	65	43	82.69%	66.15%
Needle-leafed Evergreen Forest	34	50	34	100.00%	68.00%
Mixed Forest	90	57	39	43.33%	68.42%
Cultivated Woody Vegetation	0	0	0	---	---
Cold-Deciduous Woodland	62	76	35	56.45%	46.05%
Broad-leafed Evergreen Woodland	86	74	46	53.49%	62.16%
Needle-leafed Evergreen Woodland	29	50	24	82.76%	48.00%
Mixed Woodland	71	58	29	40.85%	50.00%
Cold-Deciduous Shrub	71	85	34	47.89%	40.00%
Broad-leafed Evergreen Shrub	1	0	0	---	---
Needle-leafed Evergreen Shrub	129	197	94	72.87%	47.72%
Mixed Shrub	189	70	37	19.58%	52.86%
Desert Scrub	60	54	39	65.00%	72.22%
Totals	1800	1800	1099		

Overall Classification Accuracy = 61.06%

----- End of Accuracy Totals -----

KAPPA (K[^]) STATISTICS

Overall Kappa Statistics = 0.5792

Conditional Kappa for each Category.

Class Name	Kappa
-----	----
Unclassified	0
Open Water	0.9835
Developed Open Space	0
Developed Low Intensity	0
Developed Medium Intensity	0
Developed High Intensity	0
Barren Land	0.5309
Herbaceous Natural	0.7028
Herbaceous Cultivated	0.5611
Riparian Forested Wetland	0.805
Swamp Forested Wetland	0.7518
Shrub Wetland	0.4613
Herbaceous Emergent Wetland	0.5566
Cold-Deciduous Forest	0.4128
Broad-leafed Evergreen Forest	0.6515
Needle-leafed Evergreen Forest	0.6738
Mixed Forest	0.6676
Cultivated Woody Vegetation	0
Cold-Deciduous Woodland	0.4413
Broad-leafed Evergreen Woodland	0.6026
Needle-leafed Evergreen Woodland	0.4715
Mixed Woodland	0.4795
Cold-Deciduous Shrub	0.3754
Broad-leafed Evergreen Shrub	0
Needle-leafed Evergreen Shrub	0.4368
Mixed Shrub	0.4733
Desert Scrub	0.7126

----- End of Kappa Statistics -----